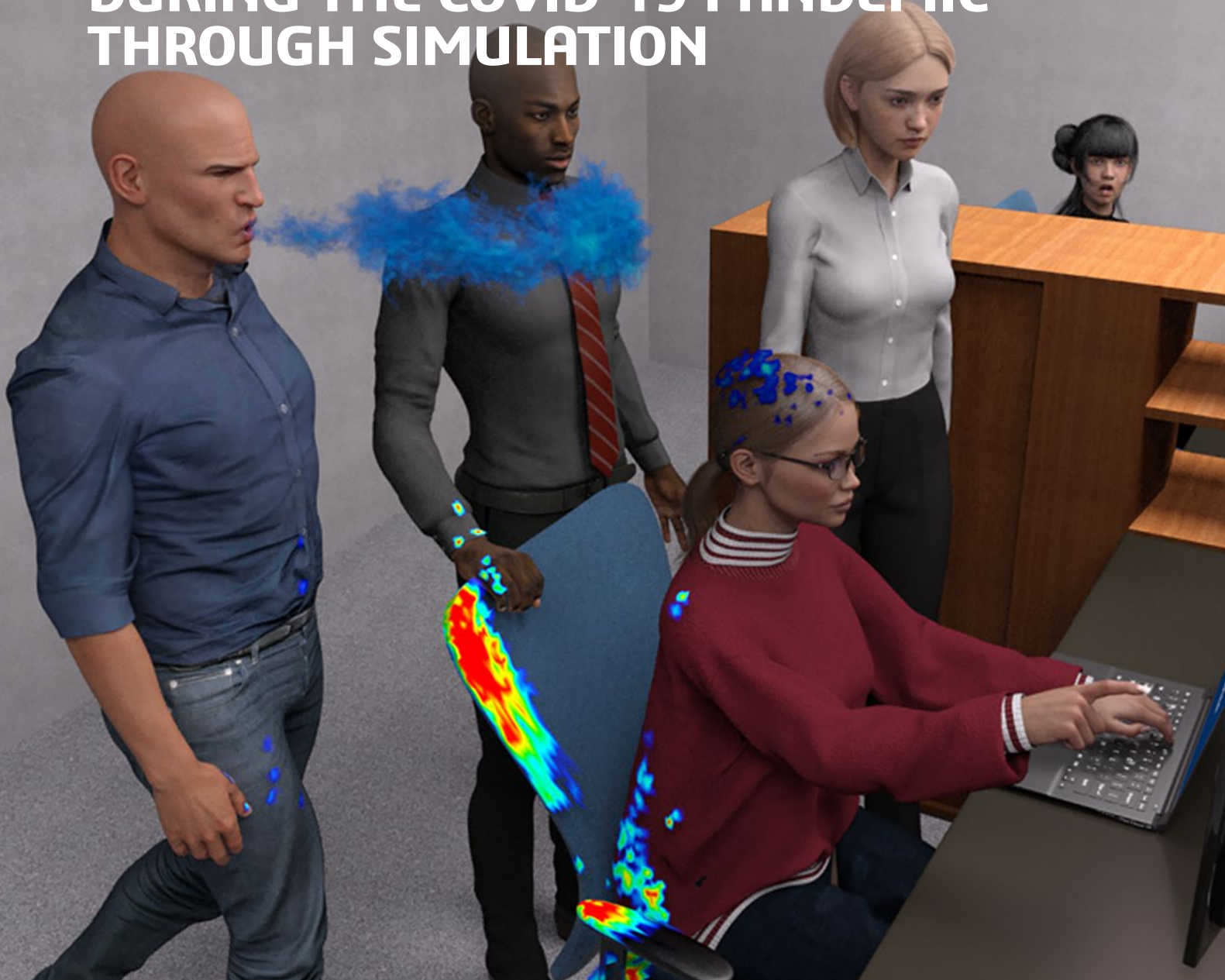


# CREATING A SAFE LIFE ENVIRONMENT DURING THE COVID-19 PANDEMIC THROUGH SIMULATION



For society to start recovering during the coronavirus disease (COVID-19) pandemic, the infrastructure of everyday life needs to be reexamined. Train carriages, aircraft cabins and car interiors will need to be redesigned to minimize the risk of transmission between passengers. Shops, schools and offices will have to change their layout to allow for social distancing. Hospitals will need to ensure that their staff has access to proper personal protective equipment (PPE) and ventilation systems that can effectively remove the virus without putting vulnerable patients, and staff, at risk. Companies will need to prove to their workers that factories, warehouse and offices are safe for them to return to work and demonstrate the importance of safety measures such as masks and shields.

This is a new challenge for many, and best practices are not always clear, or applied. Many designers, engineers and architects have never had to consider contagion in such depth before. Even management has to look into how to message properly the impact of the pandemic on company operations and product strategy. Leveraging simulation enables the analysis of the contamination risks and helps to design palliative measures. The visualization of the propagation of potentially contaminated droplets or aerosols through environments offers intelligible information for designers to act on and also provides clear, easy-to-understand images and video for businesses to use when reassuring potential investors and customers.

## INTRODUCTION

Every breath from our lungs carries with it a cloud of tiny (mainly between 0.1  $\mu\text{m}$  and 1.0  $\mu\text{m}$ ) water droplets. Such droplets can be the primary transmission vector of the SARS-CoV-2 coronavirus that leads to COVID-19. And while coughing or sneezing projects large numbers of respiratory droplets, talking and breathing also releases them. These droplets are potentially transported through the air, carried by the surrounding airflow, and can be breathed in by others. They can also deposit on surfaces that other people touch, leading to further infection if those people then touch their eyes, mouth or nose.

Individuals can be contagious for several days before symptoms manifest, and people with mild or asymptomatic cases may not realize they are infected at all. This makes it difficult to control the disease through quarantine alone. Although most countries are rapidly expanding their testing infrastructure, it is likely that some cases will escape confinement and spread of COVID-19 will continue. Managing the outbreak, especially as economic activity and daily life resumes, will require specific measures and changes to everyday environments to control the transmission of the disease.

When accounting for disease control in design, the key is to understand the transport of contaminated droplets. Simulation can model airflow through environments such as vehicle interiors, aircraft cabins, and buildings, and predict how far droplets can carry. This information can then be used to design efficient shields and personal protective equipment (PPE), or to assess the layout of a living/working space to ensure sufficient distancing is occurring. Analysis can also be leveraged to optimize ventilation and filtration systems to remove viral particles from the air, or at a minimum prevent them from contaminating clean areas.

Given the need for a rapid response to emergencies, our teams are on alert on a global scale to answer requests to help create safer healthcare facilities, life environments, and life-saving equipment like ventilators. Contact details can be found at:

<https://discover.3ds.com/simulia-covid-response>

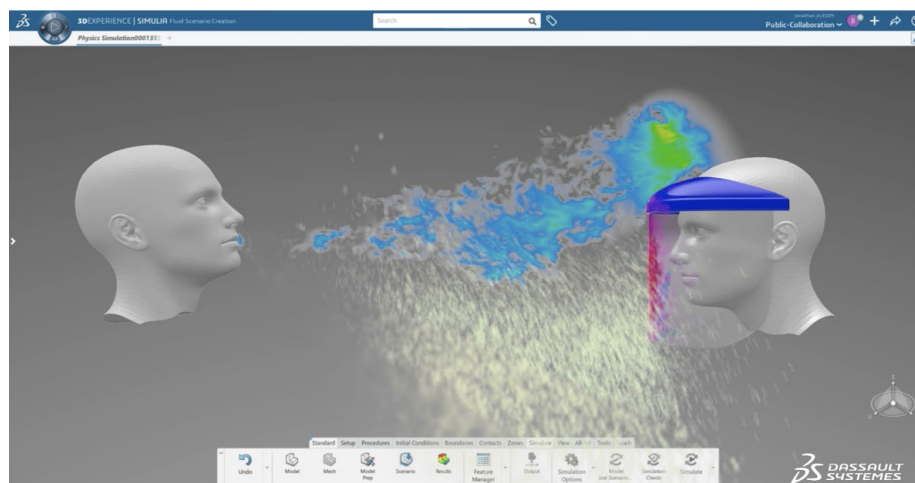


Figure 1: Sneeze simulation for testing a PPE shield, shown on the 3DEXPERIENCE platform.

Accurate cough simulation requires a solver capable of modeling both the airflow and the particle behavior of the droplets. SIMULIA CFD/Fluid solutions, powered by key technologies such as PowerFLOW and XFlow, can accurately model turbulent airflow, particle motion and tracking, as well as surface deposition in complex environments.

With thermal and acoustic simulation capabilities, SIMULIA CFD/Fluid solutions allows for the prediction of droplet propagation in combination with conventional heating, ventilation, and air-conditioning (HVAC) key performance indicators (KPIs), such as noise and heating/cooling performance to ensure safety while maintaining effectiveness and comfort. Thanks to research into the exact physical parameters of coughing, simulation offers very accurate, experimentally-verified models of cough behavior.[1][2]

The Dassault Systèmes **3DEXPERIENCE**® business platform allows for easy sharing of data and collaboration among teams. Such a platform has many advantages for breaking down silos and accelerating innovation, and it is especially useful in ensuring business continuity in conditions where business travel is impossible and many employees are working from home. The **3DEXPERIENCE** cloud computing capability complements this, giving users access to high-performance computing clusters that they cannot otherwise access at home.

## APPLICATIONS

### Shops, schools and offices

The design of most public spaces is in many ways fundamentally incompatible with social distancing recommendations. Confinement has led to a huge disruption in everyday life, from long queues outside supermarkets to extensive school closures. Getting shops, schools and offices back to normal again—so-called “de-confinement”—will be essential to repair the economic damage and lift the world out of the coronavirus recession.



Figure 2: Sneeze simulation inside an office, with and without a covered mouth.

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Building layouts from building information modeling (BIM) files in CATIA can be imported into SIMULIA CFD/Fluid solutions and converted into simulation models, complete with HVAC systems, windows and vents, and with people inside. In a typical simulation, a person inside the model coughs, or sneezes, and CFD/Fluid solutions captures the trajectory of the droplets released and predicts which surfaces are potentially contaminated. Other scenarios can also be considered, such as the effect of opening doors and windows, of changing the position of desks, or of putting plastic shielding around cashiers.

This allow facility managers to assess whether the space is safe as-is. If it fails, they can then investigate the value of both temporary measures and more permanent changes to the building's layout and HVAC. Simulation results offer visible evidence of otherwise invisible droplet spread ensuring staff, students and customers can return to a space confident that the measures put in place to reduce the risk of infection are sound.. High quality videos can be rendered from the simulation results and then used to present the measures and their effectiveness to stakeholders and the general public.

### Hospitals and nursing homes

The challenges of coronavirus for medical facilities is immense. These buildings contain both COVID-19 patients and people who are considered high risk such as the elderly, immunocompromised and those undergoing treatment for other conditions. Although these groups would be kept apart as much as possible, potential transmission routes, such as HVAC systems and drafts through doors and windows, can lead to rapid outbreaks if not identified and sealed. This is in addition to the risk to staff who work in wards with potential COVID-19 patients.

Shortages of appropriate PPE have put staff at risk, hurt morale, and limited many healthcare systems' ability to treat COVID-19. Many manufacturers, across a wide range of industries, have rapidly pivoted to producing face masks, filters, shields and even treatment devices, such as ventilators. SIMULIA simulation tools on the **3DEXPERIENCE** platform have allowed these companies to test and improve their designs and to prepare 3D printing processes to produce these components rapidly. CFD/Fluid solutions simulation can also be used to assess how effectively PPE reduces viral exposure in realistic hospital settings.

At the building level, the most important tool for preventing coronavirus spread is a strict quarantine, with no contact between COVID-19 cases and other patients. This also includes quarantining air, which is close to impossible due to the motion of staff. Airflow from hospital ventilation systems can carry droplets from one room to another, and even drafts from opening and closing doors can result in pressure differentials that draw contaminants through corridors and into other wards. Using simulation to track particle flow through the building highlights these transmission paths, and combined with the ability to simulate temperature allows users to find solutions that prevent COVID-19 spread without compromising on patient safety and comfort. Using PowerFLOW, the Hôpital Saint François in Maranges Silvanges was able to investigate how different HVAC settings and vent configurations affect pressure differentials and reduce airflow between wards.

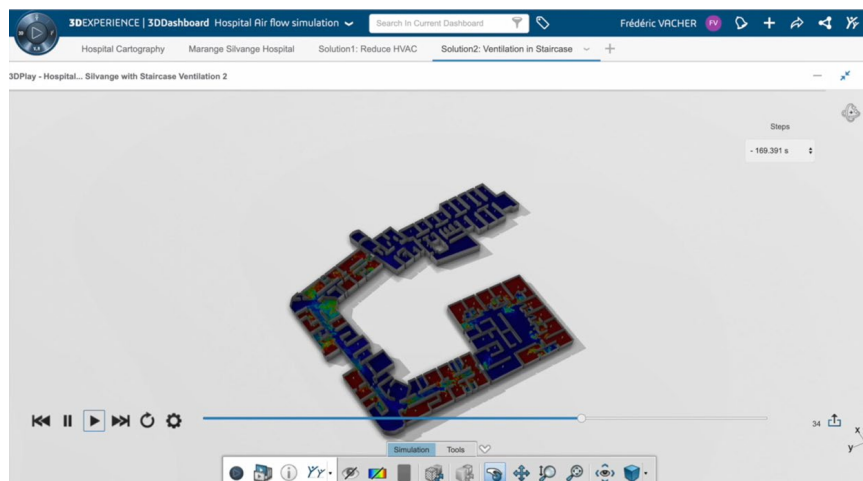


Figure 3: Contaminant propagation in Marange Silvange Hospital.

The deployment of modular field hospitals is now happening in places where healthcare systems are at risk of being overwhelmed. Time is of the essence when designing these facilities, but it is still critically important to ensure that viral droplets cannot travel between rooms and that airflow generated by HVAC systems do not put residents living in surrounding areas at risk. CFD/Fluid solutions integrates easily into many design flows, and SIMULIA cloud computing offerings give engineers easy access to high-performance computing for even faster turnaround times. China's Central-South Architectural Design Institute used XFlow to simulate virus dispersal in the Leishenshan Hospital, built in just 2 weeks in Wuhan, China.

## Aircraft

80% of all flights worldwide were grounded by mid-April 2020, and the IATA forecasts passenger numbers will remain low at least into 2021.[5] However, IATA also predicts a rapid increase in air passenger traffic if lockdowns are eased, especially for the large domestic markets in North America and Asia. Airlines that take active measures to make their aircraft safe and regain customer trust will be well-positioned in this new economic environment.

Aviation safety agencies have identified ventilation and recirculation systems as a risk factor in aircraft. The EASA for instance recommends that airlines install HEPA filters in recirculation systems and maximize fresh air flow, or else deactivate recirculation fans entirely.[6] Simulation reveals how air moves inside the cabin, and how far aerosolized droplets, which may be contaminated, can travel. This allows engineers to analyze how re-arranging vents and adding filters into the air circulation system can impede the transmission of the virus to other passengers across the cabin.



Figure 4. Simulated sneeze event with and without protective mask illustrating the capture and the distribution of projected droplets (sphere size and color proportional to droplet size).

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New design concepts for seating and cabin layouts appeared rapidly in the wake of the pandemic. These include shrouding seats in plastic "bubbles", setting some seats backwards, and replacing some rows with cargo racks for medical supplies. SIMULIA's CFD/Fluid solutions allow for rapid testing of the viability of these concepts and for the refinement of their design for speedy and successful entry into service. All sectors of the aerospace industry will have to cooperate to meet these challenges, however, all will benefit. Airlines will be able to increase passenger numbers and restart grounded routes. Maintenance, repair and overhaul (MRO) companies will see increased business as they remodel aircraft cabins and modify ventilation systems. Similarly, cabin equipment manufacturers will see demand for modification kits. Finally, the aircraft manufacturers themselves will have significant input on the remodeling and will need flights to resume to clear delivery backlogs.

Through integration of CFD/Fluid solutions with other Dassault Systèmes products such as SIMULIA or CATIA on the **3DEXPERIENCE** platform, engineers across different teams and even different companies can share data and collaborate on remodeling the cabin, while keeping sensitive data confidential. The **3DEXPERIENCE** platform can also be used to create clear, understandable and attractive visualizations of the simulation data. Airlines can use images and videos from the simulation project to demonstrate safety to potential customers and improve passenger confidence.

## Cars, buses and trains

A combination of travel restrictions and reduced public confidence has seen passenger numbers collapse across transportation sectors. In London, for example, bus ridership had fallen 85% and Tube ridership 95% by April 2020, and other cities worldwide showed similar declines.[3] Spending on ridesharing in the United States also fell by around 80% over the same time period.[4]

In the short term, a limited service of safe and reliable transit is needed to allow key workers to continue commuting. In the long term, restarting the economy will require ramping up domestic and international transport infrastructure again, while securing the confidence of the public.

Alongside deep cleaning and social distancing, several design modifications can reduce the infection risk inside vehicles and aircraft. Physical separation devices between passengers, such as plastic panels between seats and increased shielding around a driver, limits the propagation of viral droplets. Simulation has the ability to predict the airflow around these shields to assess their effectiveness, and also to enable the optimization of the design of the shields, and to assess the effectiveness of adopted safety measures.

The design of HVAC systems and the placement of vents in a vehicle cabin has a significant effect on airflow patterns and the potential propagation of droplets. Simulation not only reveals these flows, it allows engineers to test different vent configurations in order to minimize the propagation of droplets between passengers. Simulation also enables the design of efficient filter systems, identifying the proper flow and particle distribution through the filters.

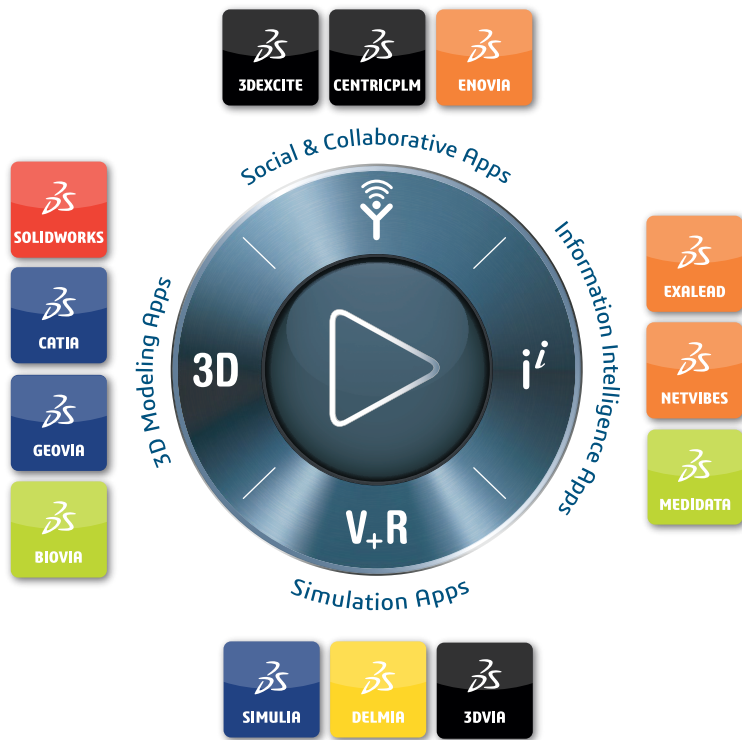
## CONCLUSION

Simulation helps engineers and designers meet the challenges of creating safe life environments during the COVID-19 pandemic. Any space where people can meet must be assessed for safety. HVAC modifications, physical barriers, masks and other PPE and rearranging spaces to allow social distancing can all reduce the risk of transmission in vehicles, aircraft and buildings. Existing hospitals can be rapidly adapted to meet the needs of the health crisis, and field hospitals can be designed and deployed quickly, usually within a few weeks.

To simulate virus propagation, companies and institutions around the world are using CFD/Fluid solutions from the SIMULIA brand of Dassault Systèmes. Cloud computing enables fast simulation of complex environments without the need for on-site hardware, minimizing the disruption of home-working and allowing rapid scaling-up for new ideas. The Dassault Systèmes **3DEXPERIENCE** platform allows users to collaborate without being physically present, and to quickly assemble design data into simulation-ready projects. Experience-focused software produces attractive and easy-to-understand images and videos for explaining propagation to the public and reassuring customers, staff and investors. Harmonizing product, nature and life, Dassault Systèmes experts can help customers find solutions to urgent problems.

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